Virtual Arm with Multimodal Biased feedback for Improving EEG Motor Imagery Calibration Training

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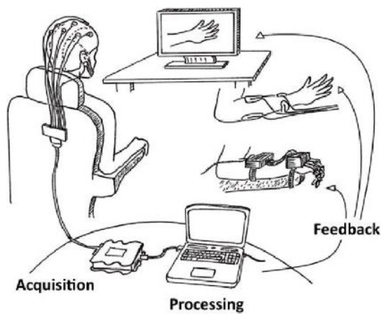
1. Introduction



Issue at hand

BCI has potential applications in restoration and rehabilitation of motor functions

However:

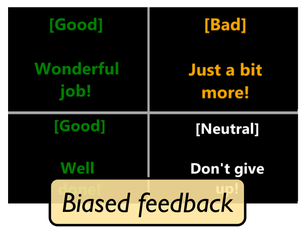
1. MI training time is often long (BCI illiteracy)
2. Robotic arms used in previous experiments are costly
3. Subjects are usually unable to visualize the kinesthetic experience

Proposed solution

Biased multimodal feedback

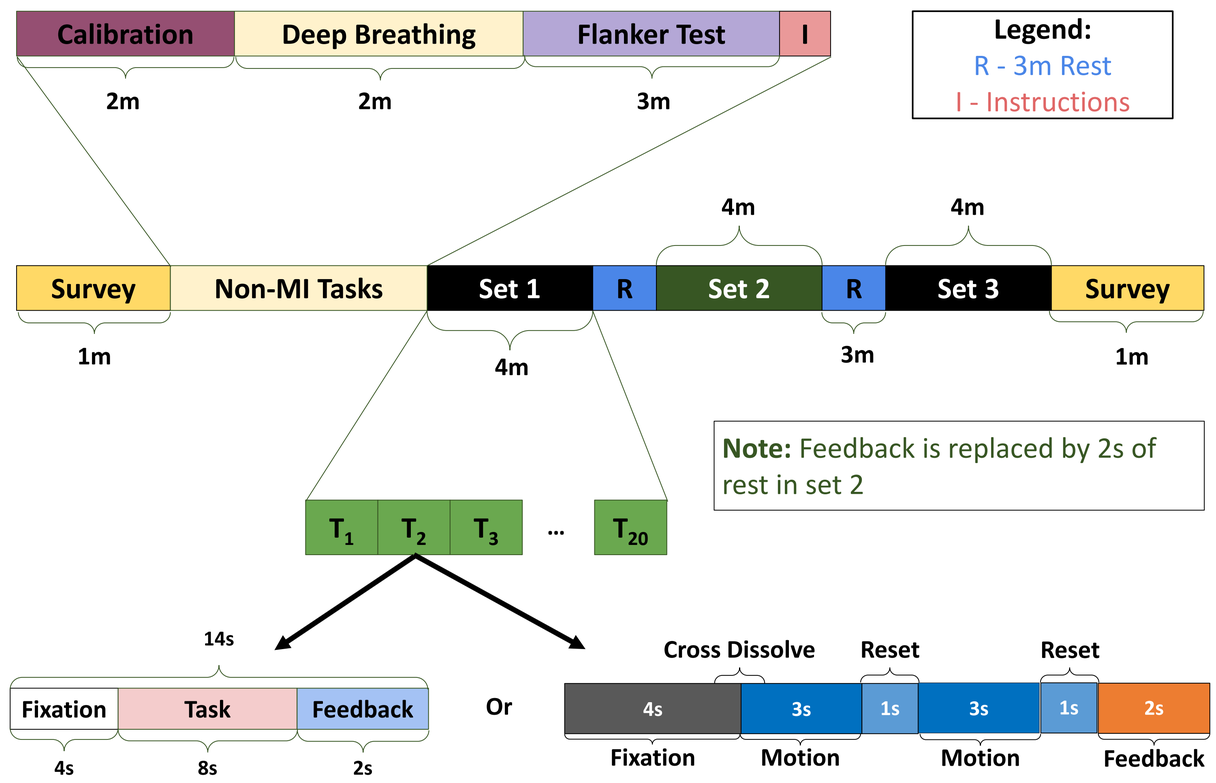
- 1. (Mostly) Positive biased feedback → Shorter total training time
- 2. Virtual robotic arm → Lower cost
- 3. Mirror therapy → Aids visualization

Virtual Arm



Biased feedback

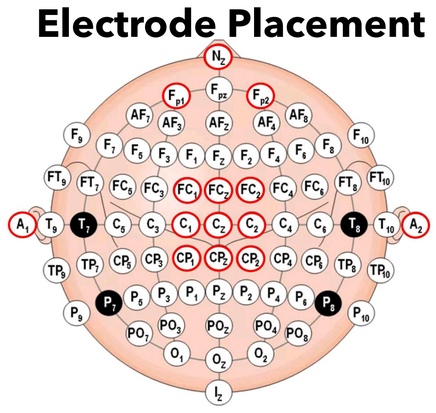
2. Experiment Design & Protocol



Motor Imagery Classes

- ❖ Moving the right arm right
- ❖ Moving the right arm left
- ❖ Reaching out with the right arm
- ❖ Grasping and relaxing right fist
- ❖ Resting No Motion (Base line)

Electrode Placement

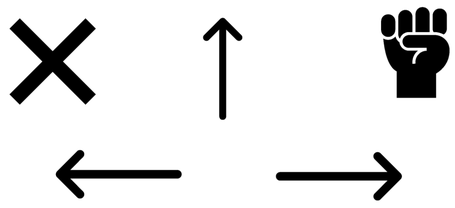


Biased Feedback

[Good] Wonderful job!	[Bad] Just a bit more!
[Good] Well done!	[Neutral] Don't give up!

Virtual Arm

No Arm



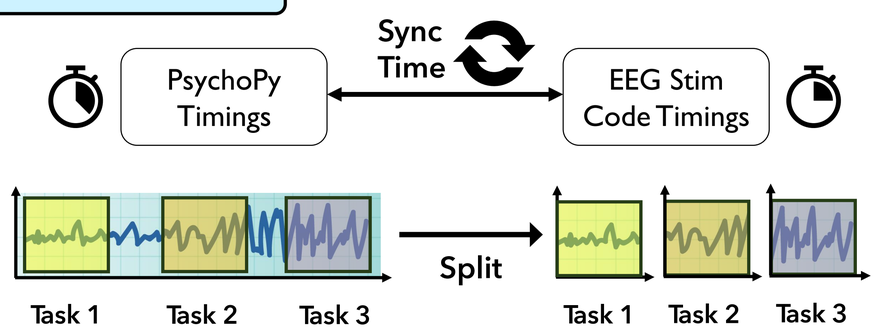
3. Data Collection & Analysis

Only **offline** processing is carried out, after the experiment.

A Stim Code Processing

Matching both timestamps

Splitting to individual trials

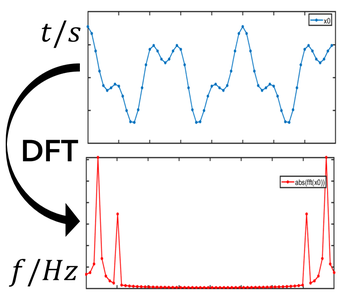


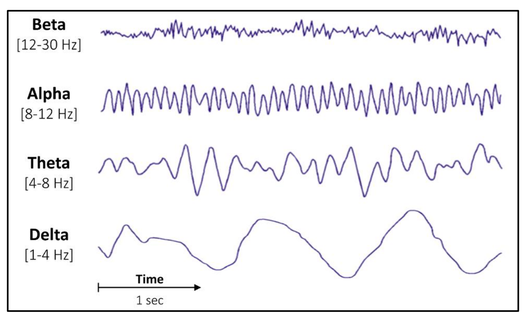
B Digital Signal Processing

Discrete FFT

High & Low Pass Filter

Remove 50Hz





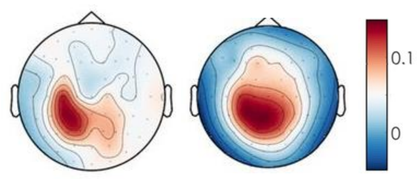
Brain waves come in multiple frequencies

C Feature Extractor & Selector

CSP Algorithm

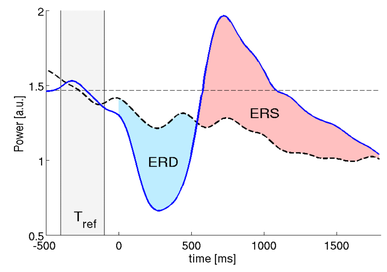
Temporal Filtering

Spatial Filtering



Different MI tasks activates different regions of the brain

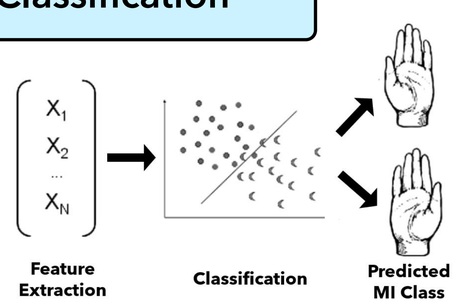
EEGs read Event-Related-Desynchronization (**ERD**) & Event-Related-Synchronization (**ERS**) waves produced during MI tasks



D Feature Classification

ML Model

SVM Classifier



75% trials
Training dataset for ML Model

25% trials
Testing dataset for ML Model

Compute **binary classification accuracy** between "relax" class & the 4 other MI classes

5-fold CV used for subject-dependent cross-validation

2D table of accuracy wrt. Subject & each MI class

4. Results & Limitations

Class	C	X	L	R	F
Accuracy (%)	98.8462	97.6923	98.8462	98.2692	99.8077

2-Sample t-Test: Unequal Variances		
Value	Set 1 + Set 3	Set 2
Mean	0.6039663	0.54367
Variance	0.0217393	0.016123
Sample Size	104	52
df	117	
t Stat	2.6464932	
P(T<=t) one-tail	0.0046262	
t Critical one-tail	1.6579817	

1. Limited trials (20x3) resulted in small training dataset
2. Physical robotic arm would be more exciting & interactive
3. Only 13 Subjects, 12 male 1 female, all NUSH students

5. Conclusion

Our research shows that biased multimodal feedback is extremely effective in boosting MI BCI classification performance

6. Future Work

Use our already trained parameters to predict which class the subject is executing for the MI task in real time

7. References

[1] Van Dokkum,et al. Brain computer interfaces for neurorehabilitation – its current status as a rehabilitation strategy post-stroke. Annals of Physical and Rehabilitation Medicine

[2] Guger C, et al. How many people are able to operate an EEG-based brain-computer interface (BCI)? IEEE Transactions on Neural Systems and Rehabilitation Engineering.